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RESEARCH MEMORANDUM

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TIME HISTORIES OF THE LOADS AND DEFORMATIONS ON THE HORIZONTAL TAIL OF A JET-POWERED BOMBER AIRPLANE IN ACCELERATED MANEUVERS AT 30,000 FEET

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RESEARCH MEMORANDUM

TIME HISTORIES OF THE LOADS AND DEFORMATIONS ON THE HORIZONTAL TAIL OF A JET-POWERED BOMBER AIRPLANE IN ACCELERATED MANEUVERS AT 30,000 FEET

By T. V. Cooney and William S. Aiken, Jr.

SUMMARY

Loads and deformations measured on the horizontal tail of a jet-powered bomber airplane in ten wind-up right-turn maneuvers and one gradual pull-up are presented in time-history form. The data were obtained at a pressure altitude of 30,000 feet and covered a Mach number range from 0.38 to 0.78 with accelerations up to 2.95g. The measured horizontal-tail loads were less than 6000 pounds and the deformations were small. The level-flight trim tail load increased in the down direction with increasing Mach number up to $M = 0.74$. At Mach numbers above 0.74 the tail load required for level flight decreased.

INTRODUCTION

The National Advisory Committee for Aeronautics is currently conducting a flight investigation to determine the tail loads on a jet-bomber airplane. For this investigation a B-45A airplane has been instrumented with strain gages for the measurements of the loads on the horizontal tail, vertical tail, and wing and with additional instruments for the measurements of the deformations which occur in the elevators, the stabilizers, and the fuselage due to aerodynamic and inertia loads.

Some immediate results showing the horizontal-tail loads and deformations are presented in this paper. The data were obtained from ten wind-up right-turn maneuvers and one gradual pull-up covering accelerations up to 2.95g and a Mach number range from 0.38 to 0.78 at a pressure altitude of 30,000 feet.

Time histories of a steady-flight run, pull-ups, and wind-up turns at 15,000 feet have previously been reported in reference 1, and time histories of a right and a left roll at 15,000 feet have been reported in reference 2.

DESCRIPTION OF AIRPLANE AND INSTRUMENTATION

The airplane used for this investigation is a B-45A. Figure 1 is a three-view drawing of the airplane showing the approximate locations of the load- and deflection-measuring devices.

Standard NACA photographic recording instruments were used to measure airspeed; altitude; rolling, pitching, and yawing velocities; sideslip angle; accelerations; control forces; and control positions. Normal, transverse, and longitudinal accelerations were measured at the airplane center of gravity and at fuselage station 714 (approx. the 1/4 root chord of the horizontal tail). Measurements of normal accelerations were also made at the midsemispan and tip of the right and left stabilizers.

An airspeed boom was mounted at the left wing tip with the airspeed head approximately 1 local chord ahead of the leading edge. The results of a flight calibration of the airspeed system for position error and an analysis of available data for a similar installation indicate that the measured Mach number differs from the true Mach number by less than ± 0.01 throughout the test range. A sideslip-angle recorder was mounted on a boom extending approximately 1 local chord ahead of the right wing at the tip.

Electrical-resistance strain-gage bridges were installed on each spar for shear and bending-moment measurements at station 18 on both sides of the horizontal tail. In addition, strain-gage bridges were installed on the elevator and rudder hinges and torque tubes in order to permit measurements of loads and torques on these control surfaces. Twist bars were installed in the horizontal stabilizers to measure the twist of the stabilizer midsemispan and tip with respect to the root.

Control-position transmitters were mounted at the root and tip of each elevator. These transmitters were wired so as to give the difference in elevator angle at the two stations due to twist of the elevator relative to the stabilizer. Additional control-position transmitters installed at the root of the elevator were used to measure the elevator position. The positions of the rudder, ailerons, and elevator spring-loaded tabs were also measured by control-position transmitters. The output from the strain gages and twist-measuring devices was recorded on two 18-channel oscillographs. A $\frac{1}{10}$-second time pulse was used to correlate the records from all recording instruments.

RESULTS AND DISCUSSION

The horizontal-tail loads and deformations together with related parameters measured in ten wind-up right-turn maneuvers and one gradual pull-up at an altitude of 30,000 feet are presented in time-history form in figures 2 to 12. All runs were made with power on and with the airplane in the clean condition. At the start of each run the airplane was trimmed in level flight. Information pertaining to the conditions of flight during each maneuver is summarized in table I.

The tail loads presented are aerodynamic loads and were obtained from the strain-gage measurements (structural load) by the addition of an inertia load. The inertia load is equal to the weight of the tail outboard of the strain-gage station multiplied by $n - 1$, where n is the tail normal acceleration.

The estimated accuracies for the quantities presented are given in the following table and are based solely on the sensitivity of the recording equipment, assuming the records can be read accurately to 0.01 inch:

Mach number	±0.01
Center-of-gravity normal acceleration, g units	±0.03
Elevator position, deg	±0.25
Total horizontal-tail aerodynamic load, lb	±160
Elevator aerodynamic load, lb (each elevator)	±60
Stabilizer twist at midsemispan, deg	±0.007
Stabilizer twist at tip, deg	±0.015
Elevator twist (relative to stabilizer), deg	±0.07

Total tail loads.- From figure 2 it is seen that at a Mach number of 0.38 the tail load for trim is 2600 pounds in the up direction. With increasing Mach number the tail load for 1 g flight becomes more negative until at $M = 0.74$, as shown in figure 10, a down-tail load of 4800 pounds is experienced. With a further increase in Mach number above 0.74, more up-tail load is required for trim. In figure 12 it is seen that at a Mach number of 0.78 the tail load for trim has changed to a down load of approximately 2000 pounds. Changing weight and center-of-gravity position are additional factors contributing to the change in tail load.

As indicated in the figures, the tail load becomes more positive with increasing normal acceleration. The increase is not linear, however, so that the tail load per g is not a constant value. The tail load per g becomes greater at the higher values of airplane normal-force coefficient, indicating a forward travel of the wing-fuselage aerodynamic center.

The tail load dissymmetry differs for each run, and except for the run made at $M = 0.78$ (fig. 12), is less than 500 pounds. In this run, the right side of the horizontal tail carries as much as 700 pounds more down load than the left.

Elevator loads and elevator position.- As shown in figure 8, the maximum elevator load measured occurred in the run made at a Mach number of 0.69. The greatest load on the left elevator was 700 pounds in the up direction at the start of the run and the greatest load on the right elevator was 650 pounds in the down direction at the time of the maximum acceleration.

There is considerable dissymmetry in elevator load, the left elevator carrying more down load in all runs. The dissymmetry is nearly constant during each run but varies for the different runs. The maximum dissymmetry is approximately 500 pounds.

The elevator position as presented in the figures is that measured at the elevator inboard end. In all runs the right elevator is approximately 0.5° more up at the root than the left.

Stabilizer and elevator twist.- At the test altitude both the stabilizer and the elevator loads are relatively small and therefore twisting of the surfaces due to these loads is small. The maximum stabilizer twist in trim flight occurred during the $M = 0.74$ run (fig. 10), where the twist at the tip of the left stabilizer is approximately 0.25° in the nose-down direction. At the same time, the twist of the right stabilizer at the tip is zero.

Due to limitations in the instrumentation, the elevator twist at the start of each run could not be determined; therefore only incremental elevator twists are given for each run. The maximum incremental elevator twist for the left-elevator-tip trailing edge was 0.46° down and occurred in run 8. At the same time, the incremental twist of the right-elevator-tip trailing edge was 0.36° down.

Buffeting.- The flight records indicated that light to heavy buffeting was experienced in all the maneuvers except those made at Mach numbers of 0.64, 0.69, and 0.72 (figs. 7 to 9) where the maximum acceleration reached was not great enough to penetrate the buffeting region at the test altitude. The normal-force coefficient at which buffeting starts is indicated in the figures. The quantities presented for all runs, however, are the mean values and do not show the oscillations produced by the buffeting.

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REFERENCES

1. Aiken, William S., Jr., and Wiener, Bernard: Time Histories of Horizontal-Tail Loads on a Jet-Powered Bomber Airplane in Four Maneuvers. NACA RM L9H16a, 1949.

2. Cooney, T. V., and McGowan, William A.: Time Histories of Loads and Deformations on a B-45A Airplane in Two Aileron Rolls. NACA RM L9I28a, 1949.

TABLE I

CONDITIONS OF FLIGHT DURING MANEUVERS

Figure	Power condition (percent rpm)	Elevator trim tab position; airplane nose up (deg)	Airplane weight (lb)	Center-of-gravity position (percent M.A.C.)	Trim Mach number
2	93	10.5	61,610	28.34	0.38
3	87	8.5	60,930	28.27	.43
4	92	6.5	59,940	28.17	.48
5	95	5.5	59,090	28.08	.53
6	100	4.0	58,500	28.02	.59
7	100	2.5	57,440	27.90	.64
8	96	1.5	56,650	27.82	.69
9	100	1.5	56,280	27.77	.72
10	100	2.5	55,780	27.72	.74
11	100	3.5	55,210	27.65	.76
12	100	4.0	54,390	27.56	.78

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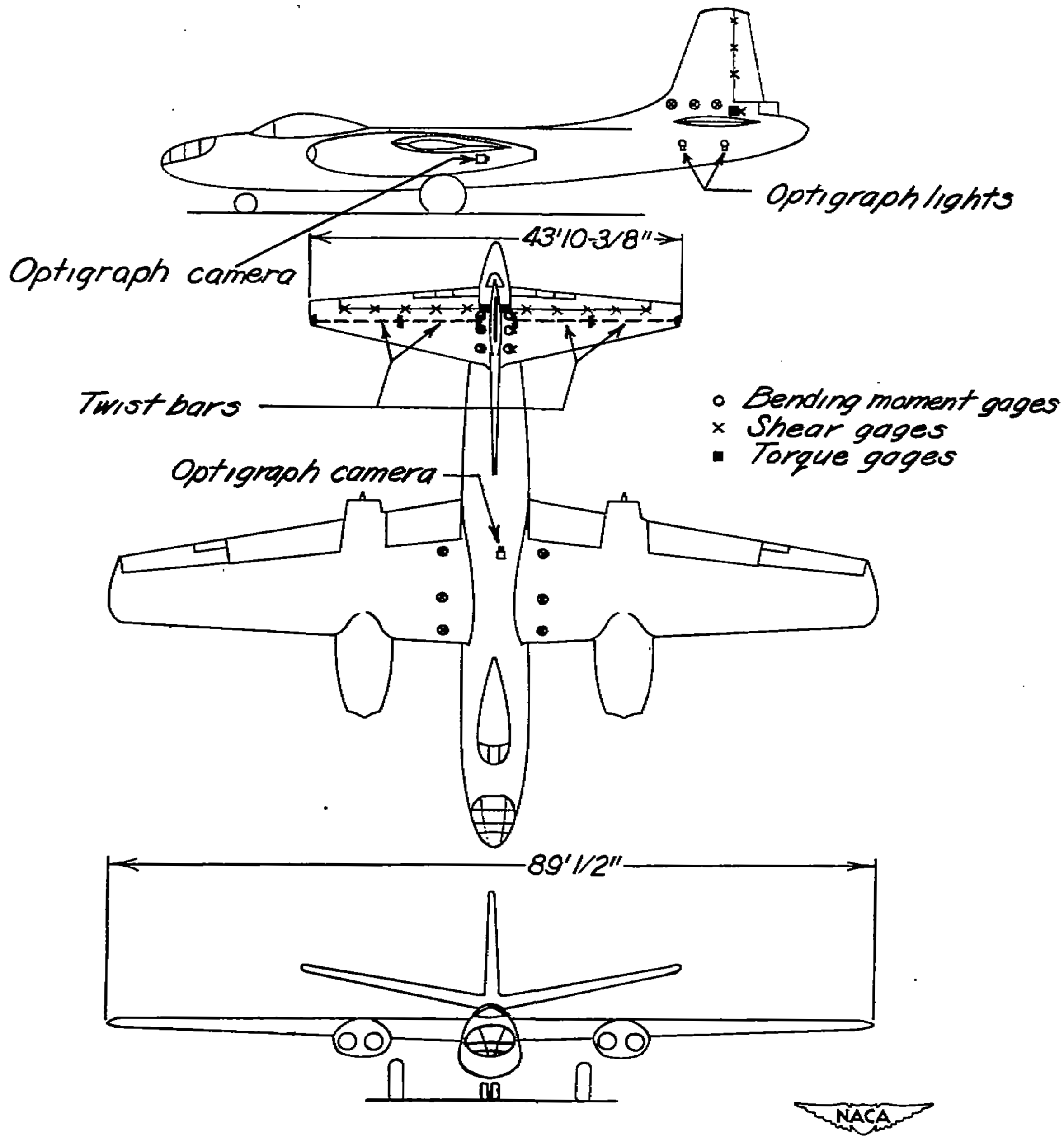

Figure 1.- Three-view drawing of test airplane showing approximate locations of strain-gage bridges and deflection-measuring devices.

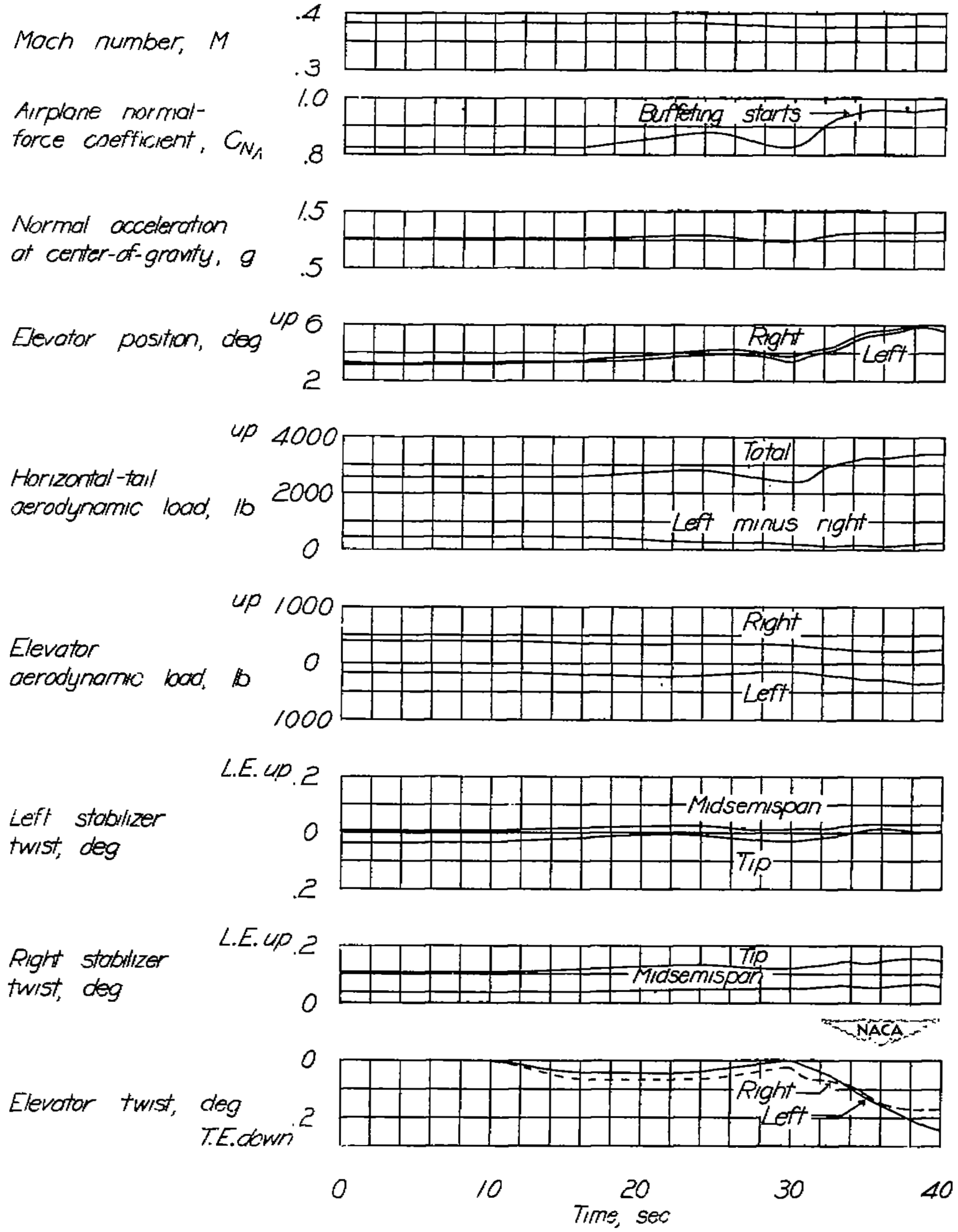

Figure 2.- Time histories of pertinent quantities measured during a wind-up right turn at M = 0.38. Airplane weight, 61,610 pounds; center of gravity at 28.34 percent mean aerodynamic chord.

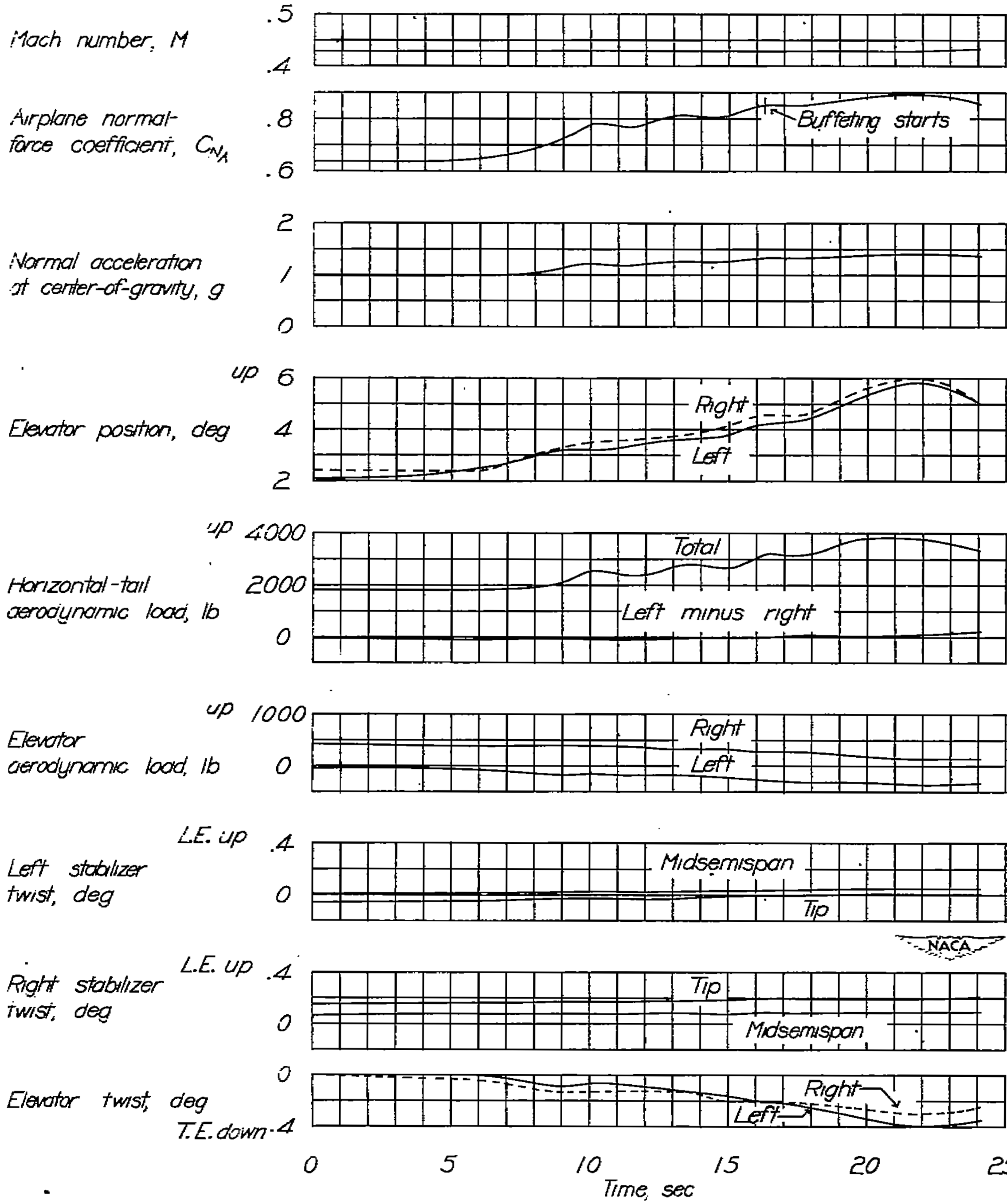

Figure 3.- Time histories of pertinent quantities measured during a wind-up right turn at M = 0.43. Airplane weight, 60,930 pounds; center of gravity at 28.27 percent mean aerodynamic chord.

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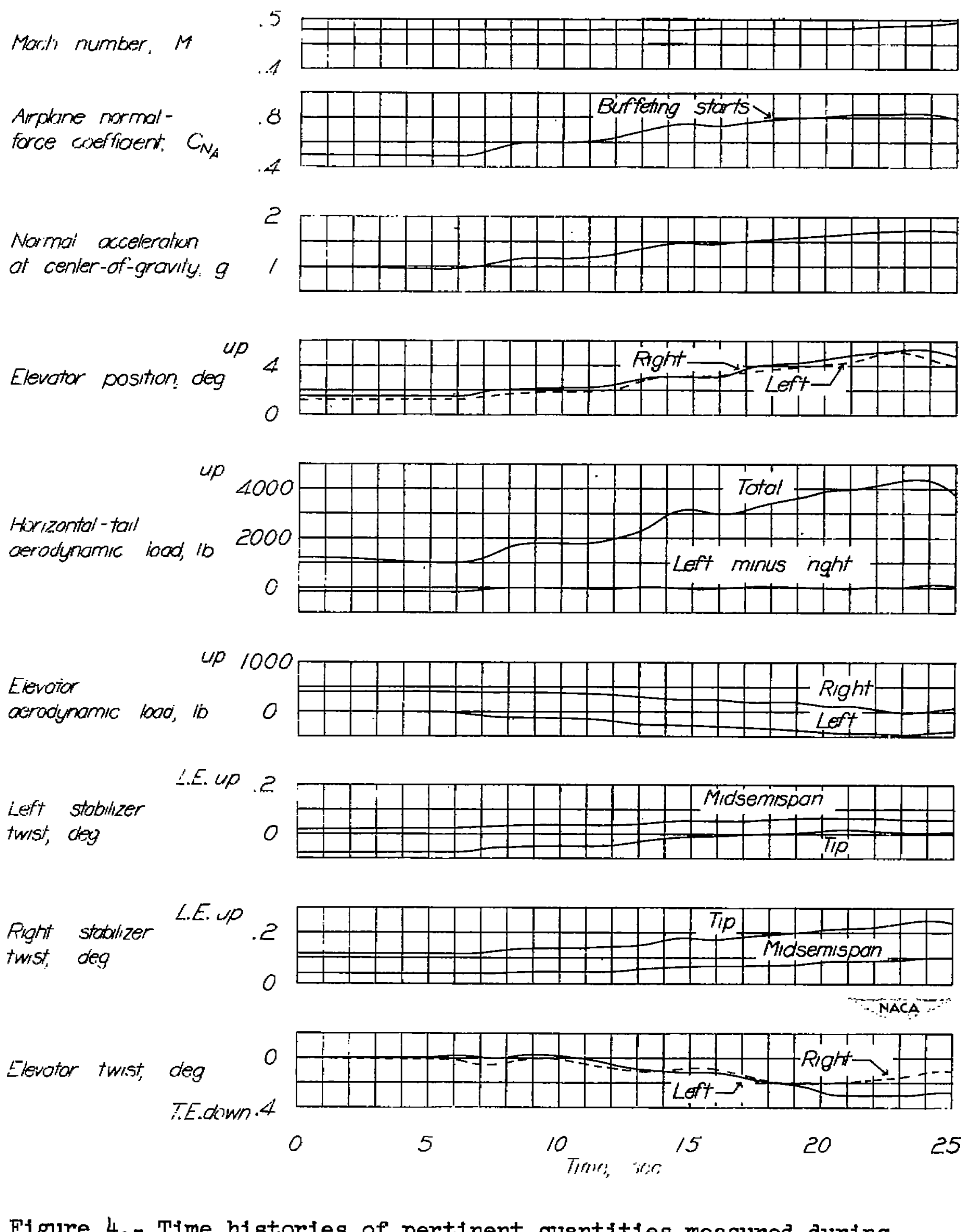

Figure 4.- Time histories of pertinent quantities measured during a wind-up right turn at M = 0.48. Airplane weight, 59,940 pounds; center of gravity at 28.17 percent mean aerodynamic chord.

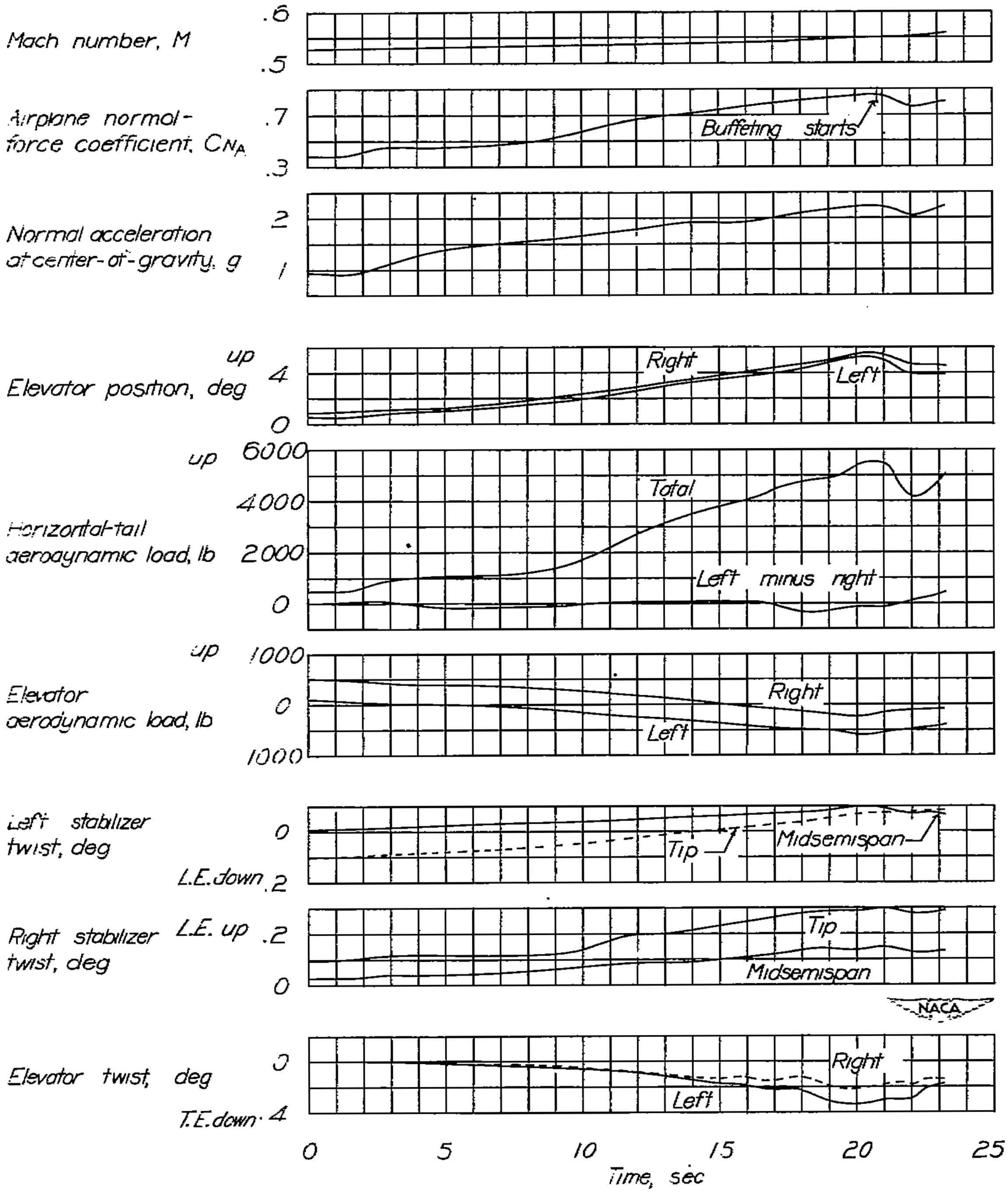

Figure 5.- Time histories of pertinent quantities measured during a wind-up right turn at M = 0.53. Airplane weight, 59,090 pounds; center of gravity at 28.08 percent mean aerodynamic chord.

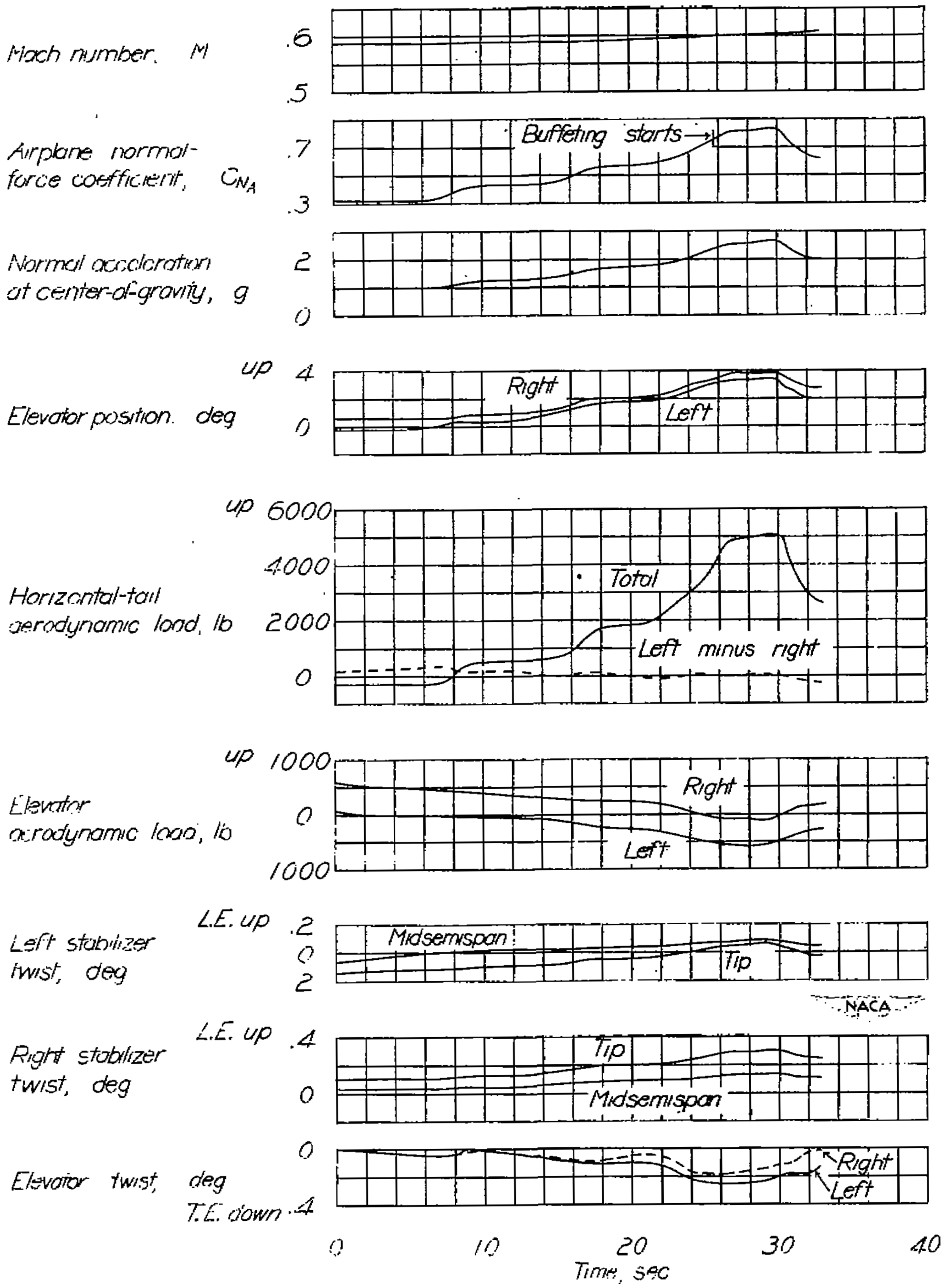

Figure 6.- Time histories of pertinent quantities measured during a wind-up right turn at M = 0.59. Airplane weight, 58,500 pounds; center of gravity at 28.02 percent mean aerodynamic chord.

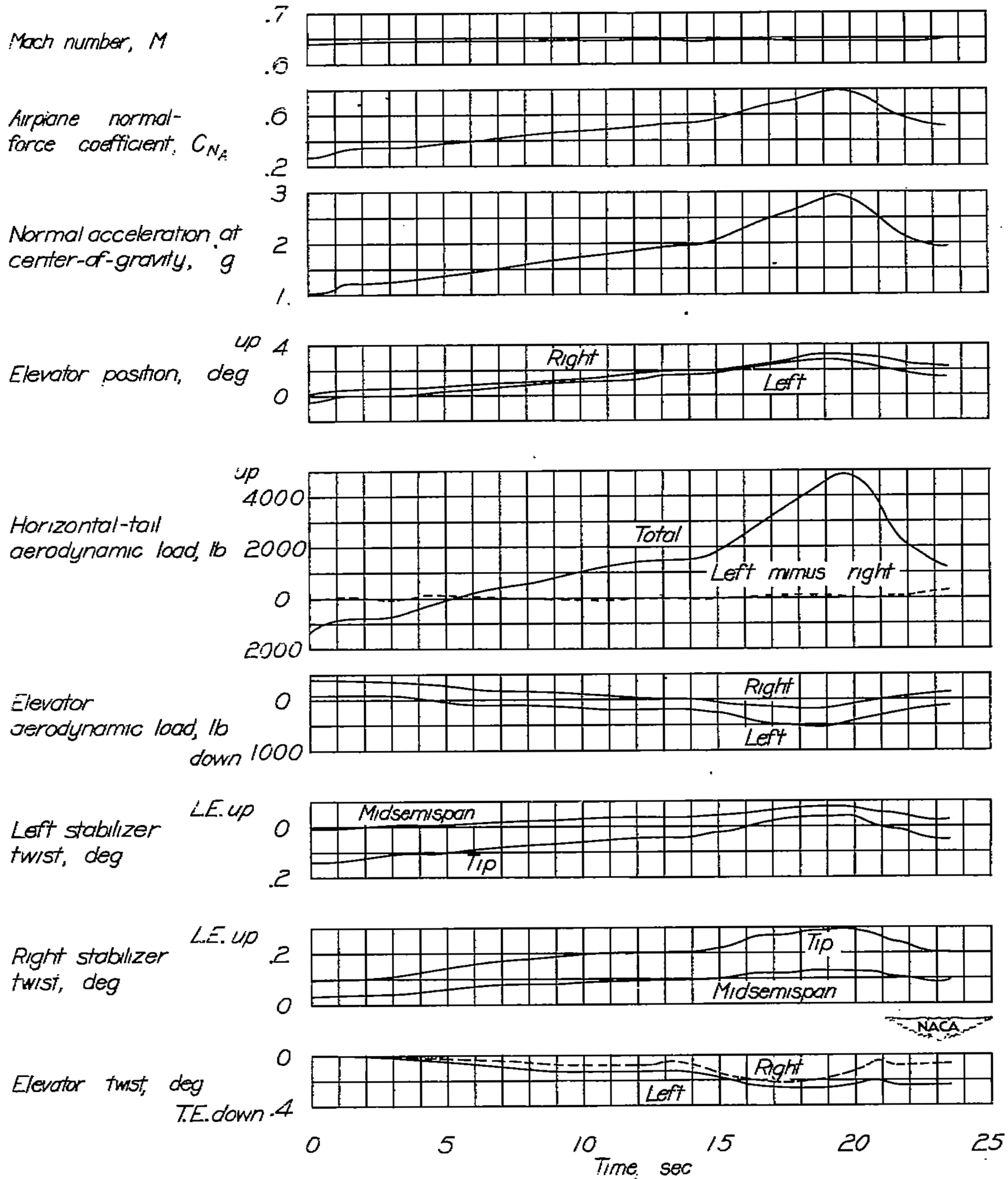

Figure 7.- Time histories of pertinent quantities measured during a wind-up right turn at M = 0.64. Airplane weight, 57,440 pounds; center of gravity at 27.90 percent mean aerodynamic chord.

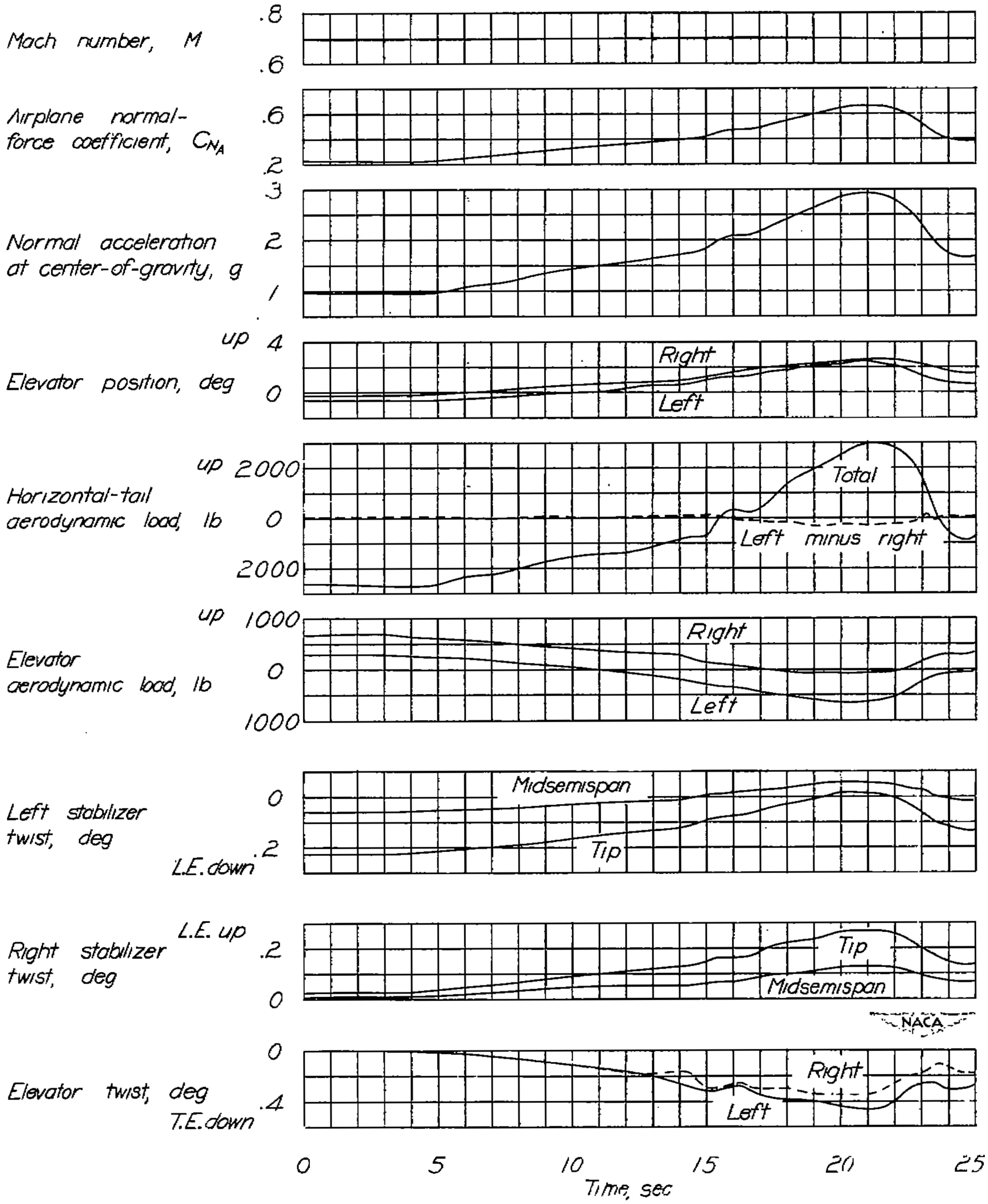

Figure 8.- Time histories of pertinent quantities measured during a wind-up right turn at M = 0.69. Airplane weight, 56,650 pounds; center of gravity at 27.90 percent mean aerodynamic chord.

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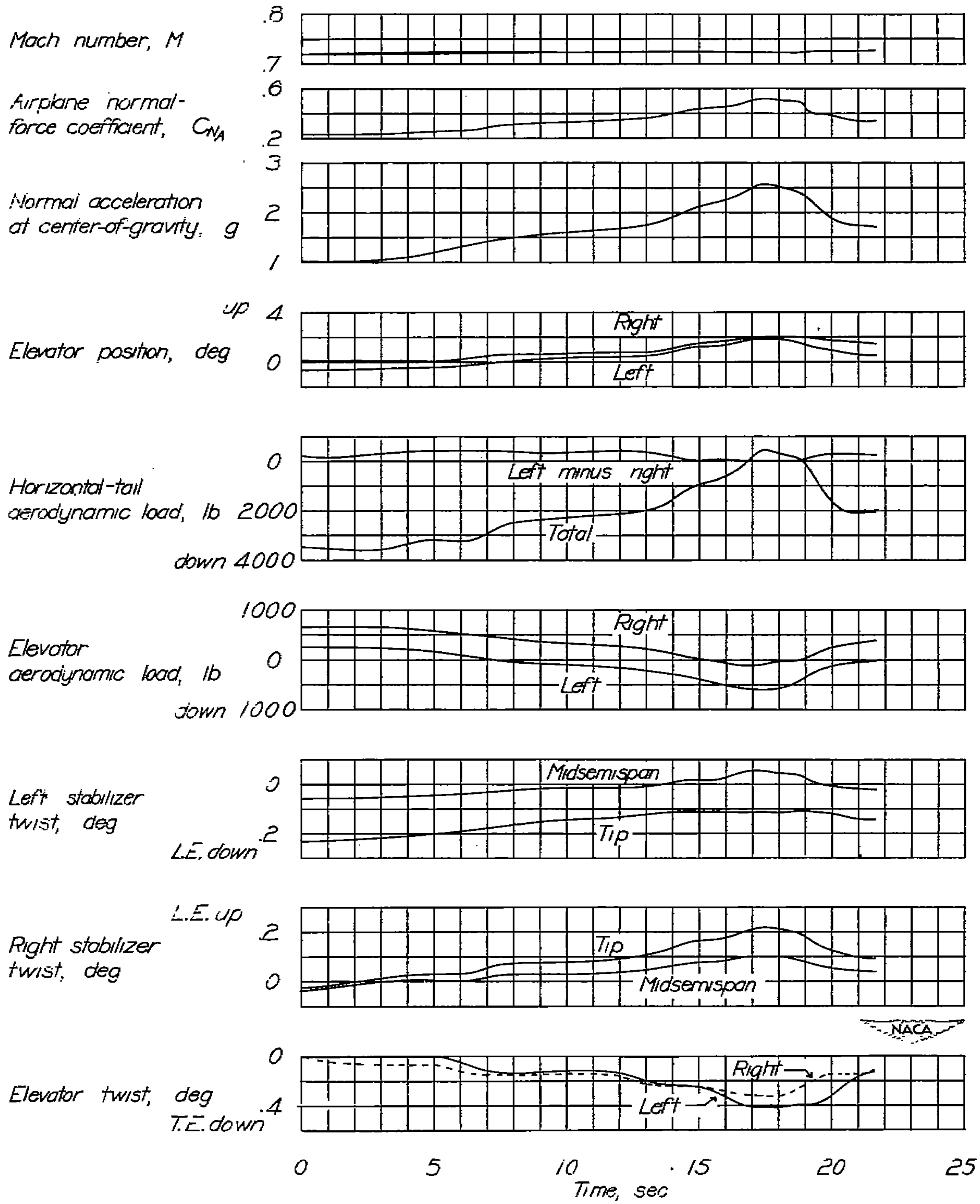

Figure 9.- Time histories of pertinent quantities measured during a wind-up right turn at $M = 0.72$. Airplane weight, 56,280 pounds; center of gravity at 27.77 percent mean aerodynamic chord.

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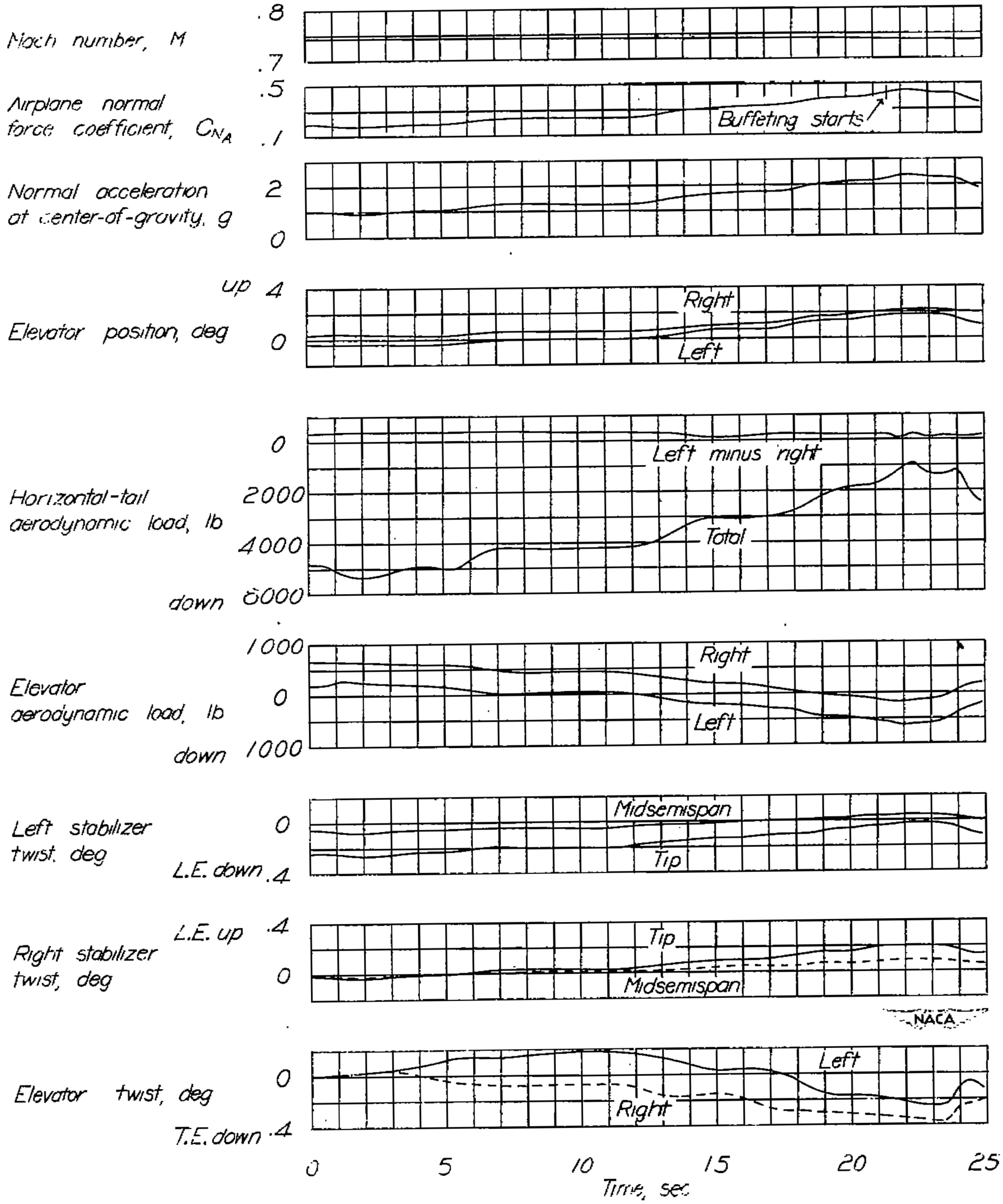

Figure 10.- Time histories of pertinent quantities measured during a wind-up right turn at $M = 0.74$. Airplane weight, 55,780 pounds; center of gravity at 27.72 percent mean aerodynamic chord.

[redacted]

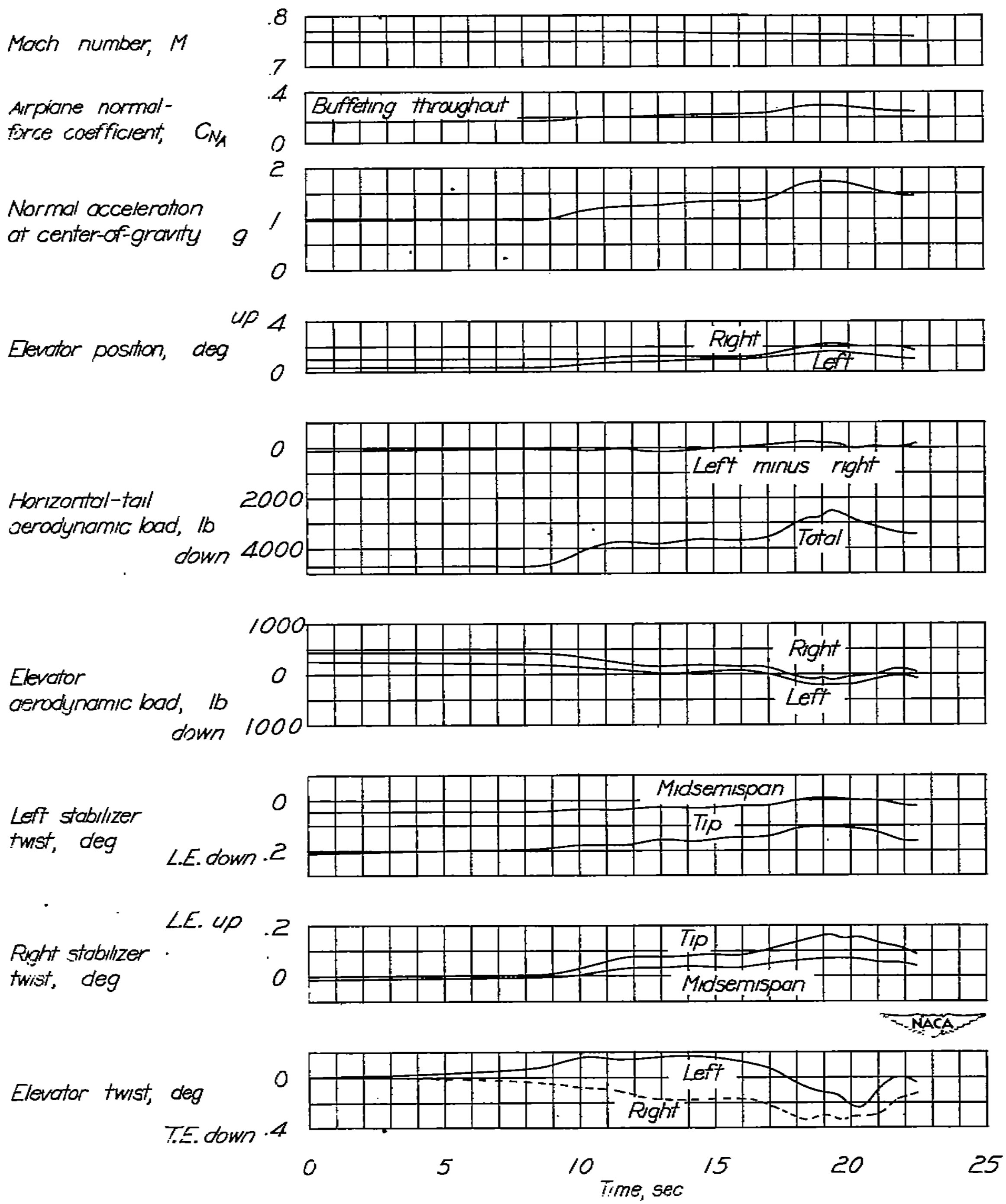

Figure 11.- Time histories of pertinent quantities measured during a wind-up right turn at M = 0.76. Airplane weight, 55,210 pounds; center of gravity at 27.65 percent mean aerodynamic chord.

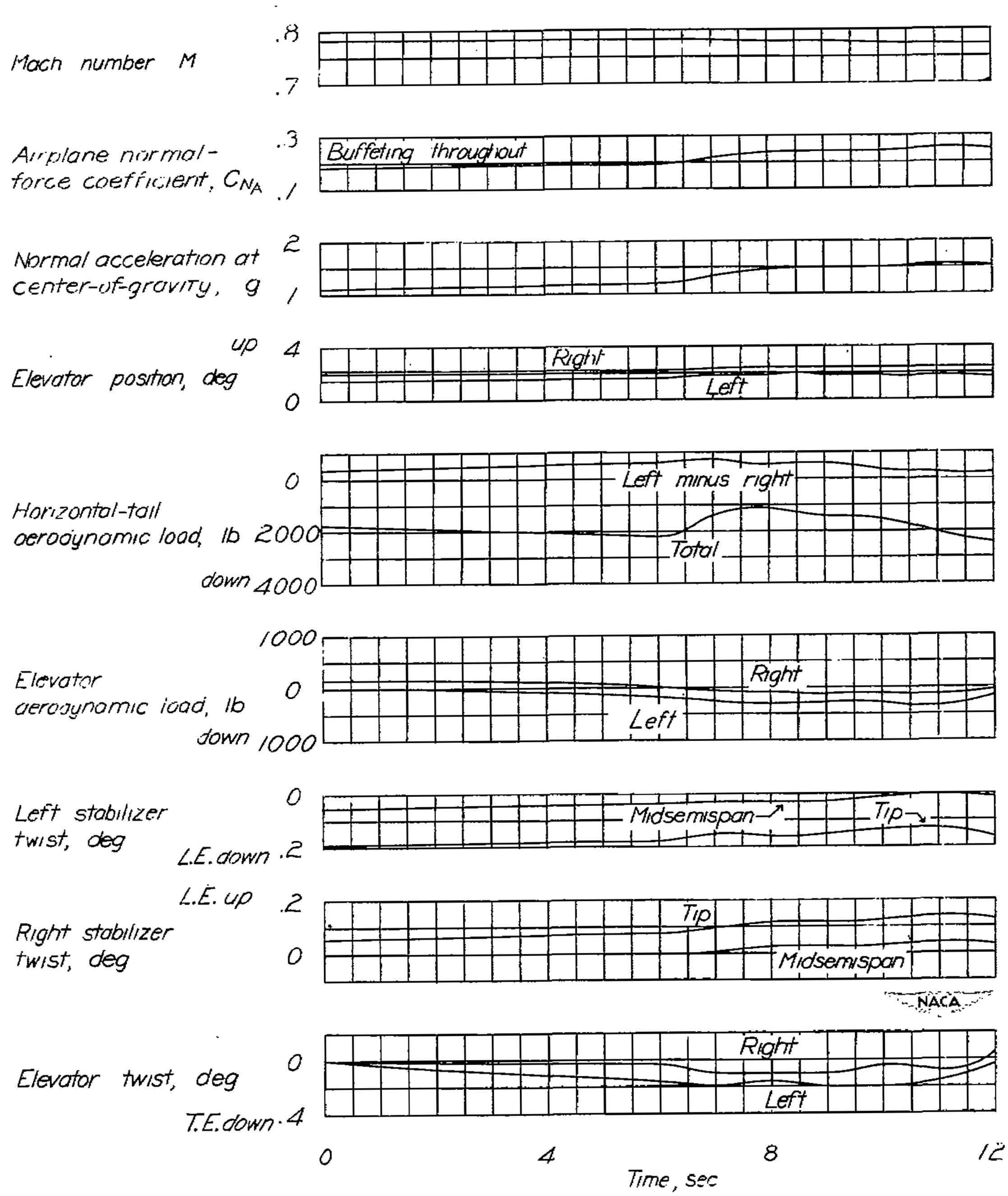

Figure 12.- Time histories of pertinent quantities measured during a gradual pull-up at M = 0.78. Airplane weight, 54,390 pounds; center of gravity at 27.56 percent mean aerodynamic chord.

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